MODERATED POSTER SESSION

1121MP Moderated Poster Session...Pediatric Cardiology: Biomechanical and Molecular Insights

Monday, March 18, 2002, Noon-2:00 p.m.
Georgia World Congress Center, Hall G

Noon

1121MP-121 Effect of Reverse Flow on the Fluid Dynamics of the Total Cavo-Pulmonary Connection: A Potential Cause of Progressive Heart Failure

Curt G. DeGroff, Wendy Orlando, Jean Hertzberg, Robin Shandas, Lilliam Valdes-Cruz, *UCHSC - The Children's Hospital, Denver, Colorado, University of Colorado, Engineering, Boulder, Colorado.*

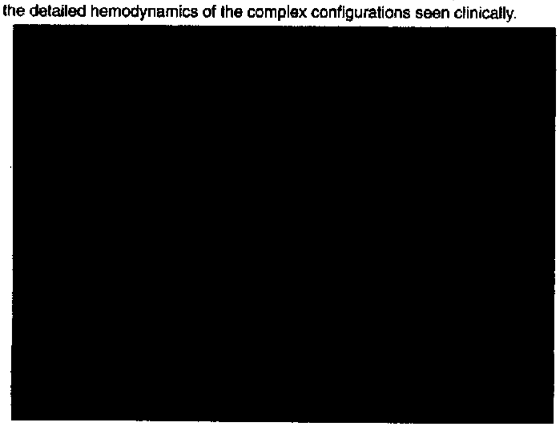
Background: The Total Cavolpulmonary Connection (TCPC), used for palliative repair of patients with single ventricle physiology, creates a passive system of blood flow into the pulmonary circulation for which energy efficiency may be critical to long term patient outcome. Clinical studies have shown reverse flow in the TCPC is an indication of heart failure. We set out to demonstrate that reverse flow leads to increased energy losses in compliant vessels. Such an effect may potentially set off a downward spiral of "decreased energy efficiency - decreased function", leading to progressive heart failure.
Methods: 3D finite volume numerical models were used to simulate flow through compliant straight vessels of 1cm diameter. Various vessel lengths were used. Two types of pulsatile flow (cardiac index 2.75 L/min/m**2) were studied: 1) typical biphasic TCPC flow (TCPC-T); 2) same as TCPC-T with reverse flow between the systolic and diastolic peaks (TCPC-R).
Results: The mean power loss was higher for reverse flow cases (range 20%-70% higher). Pressure drop dominates the power loss with larger pressure swings in the TCPC-R cases. The mean wall stress was higher in the reverse flow case as well.
Conclusions: Previous in-vitro and numerical TCPC models have not considered pulsatile flow in compliant vessels. Our preliminary numerical model studies show that in compliant walled vessels, reverse flow leads to decreased energy efficiency and increased wall stresses. This may help explain at least one of the causes of progressive heart failure in TCPC patients and may lead to novel early interventions on these patients to improve long term outcome.

12:12 p.m.

1121MP-122 An Assessment of the Major Flow Features that Affect Energy Loss and Potential for Thrombus Formation Within the Modified Total Cavo-Pulmonary Connection: Computational and Scaled In-Vitro Studies

Robin Shandas, Yottana Khunatorn, Curt DeGroff, Wendy Orlando, Shankar Mahalingam, Lilliam Valdes-Cruz, *The Children's Hospital, Denver, Colorado, University of Colorado, Boulder, Colorado.*

Background: Several studies have shown that certain geometries cause less energy loss for the modified total cavopulmonary connection (TCPC). However, less work has been done to examine the relationship between detailed flow structures and hemodynamic efficiency including the potential for TCPC thrombus formation.
Methods: Three-dimensional computer models of 4 TCPC geometries (no offset between superior (SVC) and inferior (IVC) vena cava; ½ diameter offset; 1 diameter offset; angled SVC) were created. Scaled (6X) in vitro models were also built and studied via high resolution digital particle image velocimetry (DPIV).
Results: Four major flow structures were seen: 1) secondary flow structures including helical vortices within the pulmonary arteries (PA's); 2) flow stagnation regions; 3) recirculatory regions within the PA's; 4) flow separation zones at the PA walls. The magnitude and spatial extent of these structures varied directly with energy efficiency; the ½ diameter offset produced maximum energy loss due to more extensive secondary flow structures and larger separation zones (See Figure). Measurements of maximum shear stress revealed that this geometry would have the highest possibility of thrombus formation.
Conclusions: This study sheds light on the local flow structures created by the various connections and flow configurations and provides an additional step toward understanding the detailed hemodynamics of the complex configurations seen clinically.



12:24 p.m.

1121MP-123 Indices of Diastolic Right Ventricular Function: Load-Dependence and Changes After Chronic Right Ventricular Pressure Overload in Lambs

Boudewijn P. Leeuwenburgh, Paul Steendijk, Willem A. Helbing, Jan Baan, *Leiden University Medical Center, Leiden, The Netherlands, Erasmus Medical Center - Sophia Children's Hospital, Rotterdam, The Netherlands.*

Background: In some types of congenital heart disease, the right ventricle (RV) is subjected to chronic RV pressure overload causing abnormal RV function, eventually leading to failure. Accurate quantification of diastolic function, even in the normal RV, has received little attention. Furthermore, load-dependency of RV diastolic parameters has hardly been studied.
Methods: In young lambs, the end-diastolic pressure-volume relationship (EDPVR), chamber stiffness constant (b), time-constant of isovolumic relaxation (tau) and dP/dtMin were determined using combined pressure-conductance catheters during acute inflow reduction. Measurements were done in 5 age-matched normal lambs and in 5 lambs in which the pulmonary artery was banded (PAB) at systemic (=aortic) pressures for an 8-week period using a bidirectionally adjustable band.
Results: Chronic PAB resulted in a five-fold increase of RV systolic pressure and a two-fold increase of RV wall thickness. Cardiac output decreased from 2.6±0.8 to 1.6±0.3 l/min ($p<0.05$) whereas heart rate and RV volume were unchanged. Compared to control, PAB increased both RV dP/dtMin (188±44 vs. 725±224 mmHg/s, $p<0.01$) and tau (28±4 vs. 44±16 ms, $p<0.05$). The EDPVR shifted slightly upwards and increased the stiffness constant (b) from 0.14±0.05 to 0.25±0.09 ml-1 ($p<0.05$), indicating impaired diastolic function in the hypertrophied RV. During acute pressure reduction, both dP/dtMin and tau showed a relationship with end-systolic pressure. These relationships could explain the increased dP/dtMin-value but not the increased tau-value after banding. Therefore, the increased tau after banding reflects intrinsic myocardial changes.
Conclusions: Chronic RV pressure overload results in impaired diastolic function, characterized by increased dP/dtmin and tau and decreased lusitropy. The increased dP/dtmin in the banding group can be explained by the increased systolic pressure alone and has, therefore, limited applicability as parameter of early diastolic relaxation. In spite of its load-dependence, tau seems to be a more suitable parameter to evaluate early diastolic relaxation in the RV.

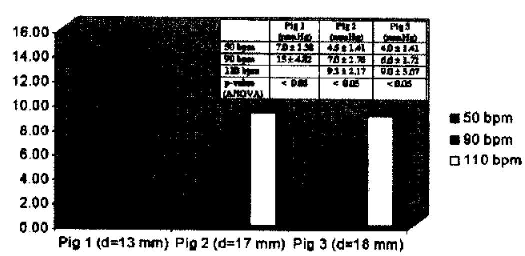
12:36 p.m.

1121MP-124 Implantation of Stents for Aortic Coarctation: Resulting Pressure Gradients at Rest and During Exercise: Studies in a Pulsatile Aortic In Vitro Model of Post Stent Coarctation

Sebastian T. Schindera, Xiaokui Li, George D. Giraud, Huifang Wang, Monica T. Young, Julia C. Swanson-Birchill, Muhammad Ashraf, Grant H. Burch, Deniz Kececioglu, David J. Sahn, *Oregon Health & Science University, Portland, Oregon, Universitaetsklinik, Freiburg, Germany.*

Background: Interposition of a stent within the aorta may result in compliance mismatch with altered pulse wave propagation. **Methods:** A pulsatile flow model of the post coarctation stented aorta was developed, using 3 fresh descending thoracic porcine aortas (each 25 cm long). The proximal segment was denatured by heating to model abnormal proximal aortic stiffness (proximal: β = 4.1 ± 0.55; distal: β = 3.5 ± 0.6), matching stiffness measurements in patients with CoA after balloon dilation. The stiffness index was calculated as $\beta = \ln[(Ps/Pd)/(Ds-Dd)]$. These were studied in a pulsatile flow system at 3 different rates (50, 90, 110 bpm) and 6 different stroke volumes (20-65 ml/beat). Endovascular stents 4 cm long (Palmaz type 4010) were implanted and expanded to the diameter of the aorta (pig 1: 13mm; pig 2:17mm; pig 3: 18mm) between the stiffened and distal segment with no apparent narrowing of the lumen. Aortas were imaged by intravascular ultrasound for dynamic dimension changes, and systolic peak to peak pressure gradients were determined by high fidelity catheter pullback. **Results:** Small peak to peak pressure gradients increased significantly with heart rate and flow, and there were higher gradients in the smaller diameter aorta ($p < 0.05$). **Conclusions:** The placement of a long noncompliant aortic stent interposes a rigid, noncompliant segment and results in small gradients at rest and exercise even in the absence of apparent obstruction.

Mean Peak to Peak Pressure Gradient (mmHg)



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